ORANGE ROUGHY, CAPE RUNAWAY TO BANKS PENINSULA (ORH 2A, 2B, 3A)

1. FISHERY SUMMARY

1.1 Commercial fisheries

The first reported landings of orange roughy between Cape Runaway and Banks Peninsula were in 1981–82 occurring with the development of the Wairarapa fishery. Total reported catches and TACCs grouped into the three orange roughy Fishstocks from 1981–82 to 2012–13 are shown in Table 1. The historical catches and TACCs for these stocks are shown in Figure 1.

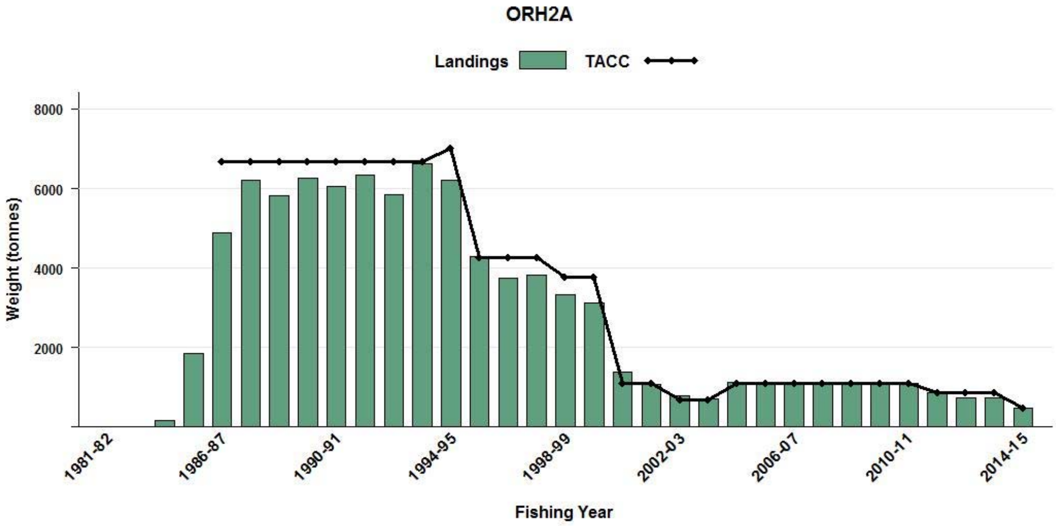
Table 1: Reported catches (t) and TACCs (t) from 1981–82 to 2014–15. QMS data from 1986–present.

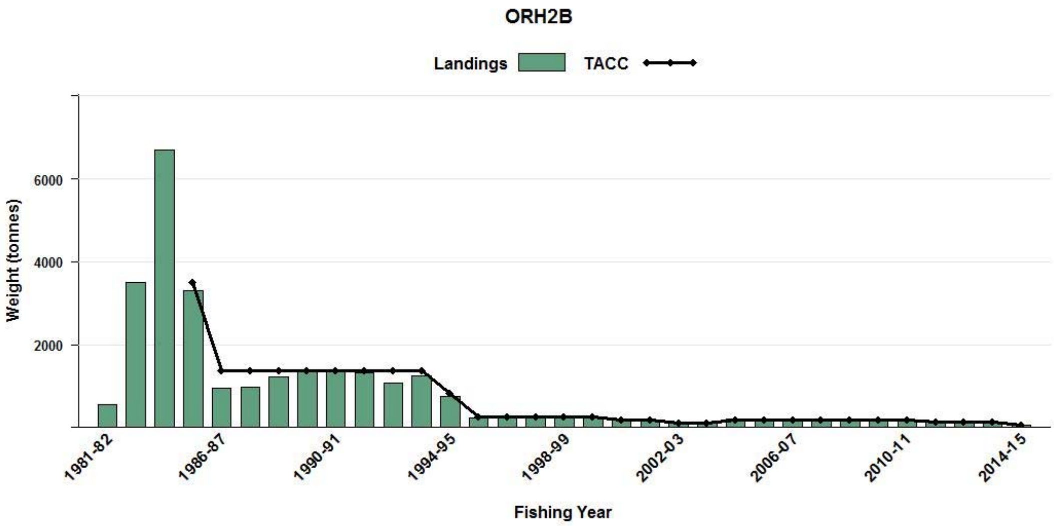
Fishing Year (1 Oct–30 Sep)	QMA 2A (Ritchie + E.Cape)		QMA 2B (Wairarapa)		QMA 3A (Kaikoura)		All areas combined	
	Catches	TACC	Catches	TACC	Catches	TACC	Catches	TACC or catch limit
1981–82*	-	-	554	-	-	-	554	-
1982–83*	-	-	3 510	-	253	-	3 763	-
1983–84†	162	-	6 685	-	554	-	7 401	-
1984–85†	1 862	-	3 310	3 500	3 266	§	8 438	-
1985–86†	2 819	4 576	867	1 053	4 326	2 689	8 012	8 318
1986–87	5 187	5 500	963	1 053	2 555	2 689	8 705	9 242
1987–88	6 239	5 500	982	1 053	2 510	2 689	9 731	9 242
1988–89	5 853	6 060	1 236	1 367	2 431	2 839	9 520	10 266
1989–90	6 259	6 106	1 400	1 367	2 878	2 879	10 537	10 352
1990–91	6 064	6 106	1 384	1 367	2 553	2 879	10 001	10 352
1991–92	6 347	6 286	1 327	1 367	2 443	2 879	10 117	10 532
1992–93	5 837	6 386	1 080	1 367	2 135	2 879	9 052	10 632
1993–94	6 610	6 666	1 259	1 367	2 131	2 300	10 000	10 333
1994–95	6 202	7 000	754	820	1 686	1 840	8 642	9 660
1995–96	4 268	4 261	245	259	612	580	5 125	5 100
1996–97	3 761	4 261	272	259	580	580	4 613	5 100
1997–98	3 827	4 261	254	259	570	580	4 651	5 100
1998–99	3 335	3 761	257	259	582	580	4 174	4 600
1999–00	3 120	3 761	234	259	617	580	3 971	4 600
2000–01	1 385	1 100	190	185	479	415	2 054	1 700
2001–02	1 087	1 100	180	185	400	415	1 667	1 700
2002–03	782	680	105	99	235	221	1 122	1 000
2003–04	703	680	103	99	250	221	1 056	1 000
2004–05	1 120	1 100	206	185	416	415	1 742	1 700
2005–06	1 076	1 100	172	185	415	415	1 663	1 700
2006–07	1 131	1 100	203	185	401	415	1 736	1 700
2007–08	1 068	1 100	209	185	432	415	1 709	1 700
2008–09	1 114	1 100	173	185	414	415	1 701	1 700
2009–10	1 117	1 100	213	185	390	415	1 720	1 700
2010–11	1 113	1 100	158	185	420	415	1 690	1 700
2011–12	876	875	140	140	428	415	1 445	1 430
2012–13	727	#710	102	#106	296	#314	1 124	#1 130
2013–14	732	875	108	140	331	415	1 171	1 430
2014–15	483	488	54	60	156	177	693	725

* Ministry data † FSU data. § Included in QMA 3B TAC.
\# Includes shelving (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC)

There was a major change in the ORH 2A fishery in 1993–94 with a shift of effort from the main spawning hill on Ritchie Bank to hills off East Cape. Although these hills had apparently only been lightly fished in the past, during 1993–94 52% of the total catch from ORH 2A was taken from the East Cape area (Table 2). This led to an agreement between industry and the Minister responsible for fisheries that, from 1994–95, the traditionally fished areas within ORH 2A (south of 38°23', hereafter referred to as “2A South”) would be managed separately from the new East Cape fishery (north of 38°23', “2A North”). ORH 2A South was combined with ORH 2B and ORH 3A to form the Mid-East Coast (MEC) stock for management purposes.

The catch limits for these two areas changed three times in the following four years, including a subdivision of 2A North (Table 3). Catches in the exploratory sub-area of 2A North never approached the catch limit, with only 37 t being caught in 1996–97 and less in subsequent years.





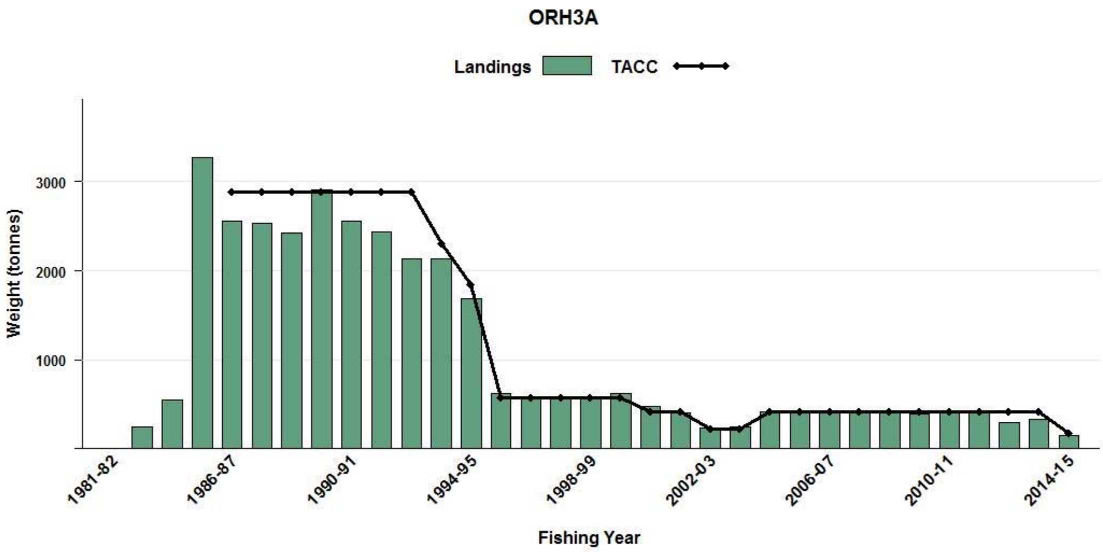


Figure 1: Reported commercial landings and TACCs for ORH 2A (Central (Gisborne)), ORH 2B (Central (Wairarapa)), and ORH 3A (Central/Challenger/South-East (Cook Strait/Kaikoura)).

For the 2000–01 fishing year, the TACC for ORH 2A was reduced to 1100 t, that for ORH 2B to 185 t, and that for ORH 3A to 415 t. Within the TACC for ORH 2A, the catch limit for all of 2A North was reduced to 200 t, without specifying separate catch limits for the East Cape Hills and the exploratory area, while the catch limit for 2A South was reduced to 900 t. This gave a catch limit for the MEC stock of 1500 t. The catch limit for MEC was reduced to 800 t (and ORH 2A South to 480 t) for the 2002–03 and 2003–04 fishing years. From 1 October 2004 there was an increase in the TACC to 1100 t, 185 t, and 415 t in 2A, 2B, and 3A respectively. Furthermore, an allowance of 58 t, 9 t, and 21 t, for other mortality was allocated to 2A, 2B, and 3A in 2004 as well.

In 2012–13 the fishing industry voluntarily shelved (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC) approximately 25% of the MEC quota, resulting in effective catch limits of 510 t, 106 t, and 314 t for 2A South, 2B, and 3A respectively.

1.2 Recreational fisheries
Recreational fishing for orange roughy is not known in this area.

1.3 Customary non-commercial fisheries
No information on customary non-commercial fishing for orange roughy is available for this area.

1.4 Illegal catch
No information is available about illegal catch in this area.

Table 2: North Mid-East Coast + East Cape (ORH 2A) catches by area, in tonnes and by percentage of the total ORH 2A catch. (Percentages up to 1993–94 and from 2007–08 calculated from Ministry data; 1994–95 to 1996–97 from NZFIB data, and 1997–98 to 2006–07 from Orange Roughy Management Co.) Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, and ORH 3A combined) catches in tonnes.

Fishing year	2A North		2A South		MEC (t)
	t	%	t	%	
1983–84	0	0	162	100	7 401
1984–85	4	< 1	1 858	99	8 434
1985–86	41	1	2 778	99	7 971
1986–87	253	5	4 934	95	8 452
1987–88	36	< 1	6 203	99	9 695
1988–89	143	2	5 710	98	9 377
1989–90	20	< 1	6 239	99	10 517
1990–91	13	< 1	6 051	99	9 988
1991–92	18	< 1	6 329	99	10 099
1992–93	30	< 1	5 807	99	9 022
1993–94	3 437	52	3 173	48	6 563
1994–95	2 921	47	3 281	53	5 721
1995–96	3 235	76	1 033	24	1 890
1996–97	2 491	66	1 270	34	2 122
1997–98	2 411	63	1 416	37	2 240
1998–99	1 901	57	1 434	43	2 273
1999–00	1 456	47	1 666	53	2 517
2000–01	302	22	1 083	78	1 752
2001–02	186	17	901	83	1 480
2002–03	173	24	546	76	886
2003–04	170	24	533	76	886
2004–05	271	24	849	76	1 471
2005–06	216	20	859	80	1 445
2006–07	229	20	902	80	1 506
2007–08	200	24	868	76	1 509
2008–09	230	21	884	79	1 471
2009–10	267	24	850	76	1 453
2010–11	207	19	906	81	1 484
2011–12	184	21	692	79	1 260
2012–13	190	26	537	74	935
2013–14	176	25	530	75	5 315
2014–15	179	42	248	58	458

Table 3: Catch limits (t) by sub-area within ORH 2A, as agreed between the industry and the Minister responsible for fisheries since 1994–95 and the catch limit for the Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, ORH 3A combined). (Note that 2A North was split, for the years 1996–97 to 1999–2000, into the area round the East Cape Hills and the remaining area, which is called the exploratory area).

Fishing year	2A North	2A South	MEC
1994–95	3 000	4 000	6 660
1995–96	3 000	1 261	2 100
1996–97	3 000*	1 261	2 100
1997–98	3 000*	1 261	2 100
1998–99	2 500*	1 261	2 100
1999–00	2 500*	1 261	2 100
2000–01	200	900	1 500
2001–02	200	900	1 500
2002–03	200	480	800
2003–04	200	480	800
2004–05	200	900	1 500
2005–06	200	900	1 500
2006–07	200	900	1 500
2007–08	200	900	1 500
2008–09	200	900	1 500
2009–10	200	900	1 500
2010–11	200	900	1 500
2011–12	200	675	1 230
2012–13	200	510	930
2013–14	200	510	930
2014–15	200	208	525

*Catch limit for East Cape Hills including 500 t for the exploratory area.

1.5 Other sources of mortality

There has been a history of catch overruns in this area because of lost fish and discards, particularly in the early years of the fishery. In the assessments presented here total removals were assumed to exceed reported catches by the overrun percentages in Table 4.

All yield estimates and forward projections presented make an allowance for the current estimated level of overrun of 5%.

Table 4: Catch overruns (%) by QMA and year. -, no catches reported.

Year	2A (North and South)	2B	3A
1981–82	-	30	-
1982–83	-	30	30
1983–84	50	30	30
1984–85	50	30	30
1985–86	50	30	30
1986–87	40	30	30
1987–88	30	30	30
1988–89	25	25	25
1989–90	20	20	20
1990–91	15	15	15
1991–92	10	10	10
1992–93	10	10	10
1993–94	10	10	10
1994–95 and subsequent years	5	5	5

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy Introduction section.

3. STOCKS AND AREAS

Two major spawning locations have been identified in ORH 2A, one at the East Cape Hills in "2A North" and the other on the Ritchie Bank in "2A South". Spawning orange roughy were located in Wairarapa (ORH 2B) in winter 2001, but no large concentrations were found, and the significance of this spawning event is not known. Spawning orange roughy have not been located in Kaikoura (ORH 3A). The major spawning area in ORH 2A South, ORH 2B, and ORH 3A is still believed to be the Ritchie Bank, although spawning aggregations were not seen here in the 2013 AOS survey.

Results from allozyme studies showed that orange roughy from the three areas, "2A South", Wairarapa, and Kaikoura could not be separated, but were distinct from fish on the eastern Chatham Rise. Earlier analyses that suggested there was a genetic stock boundary between East Cape and Ritchie Bank were not supported by a more recent replicate sample from East Cape. For these reasons, orange roughy in this region are currently treated as two stocks: the Mid-East Coast (MEC) stock (2A South, Wairarapa, and Kaikoura) and the East Cape (EC) stock (2A North). The relationship between these areas and the location of the main fishing grounds is shown in Figure 2.

4. STOCK ASSESSMENT

Stock assessments are reported below for East Cape from 2003 and for Mid East Coast (MEC) from 2014.

4.1 East Cape stock (2A North)

The stock assessment for the East Cape was last updated in 2003 and is summarised here (Anderson 2003b). An attempt to update the assessment with a new set of CPUE indices was made in 2006, but was rejected by the Working Group because of changes in the fishery which invalidated the utility of the CPUE series as an index of abundance. With no other abundance estimates available, an updated stock assessment was not possible.

4.1.1 Assessment Inputs

A CPUE analysis was performed in 2006, but was considered unreliable because of a change in fishing patterns and fleet size corresponding to the reduction of the catch limit to 200 t in 2000–01. The CPUE analysis was updated in 2011 and was considered more reliable by the Working Group due to the increase in the number of trawls per year since 2006. The 2011 analysis showed that standardised CPUE decreased after a peak in 2003–04, and has subsequently remained at a level similar to that in the late 1990s to early 2000s (Table 5).

Previous concerns by the Working Group that the fishery was dominated by a single vessel were alleviated somewhat by the return or entry of three other vessels to the fishery since 2003–04, but the utility of CPUE analyses in fisheries where substantial catch limit reductions have caused major changes in fishing patterns remains an issue for this stock.

The model inputs for the 2003 stock assessment were catches, an egg survey, and CPUE indices (Table 5). The biological parameters used are presented in the Biology section at the beginning of the Orange Roughy section.

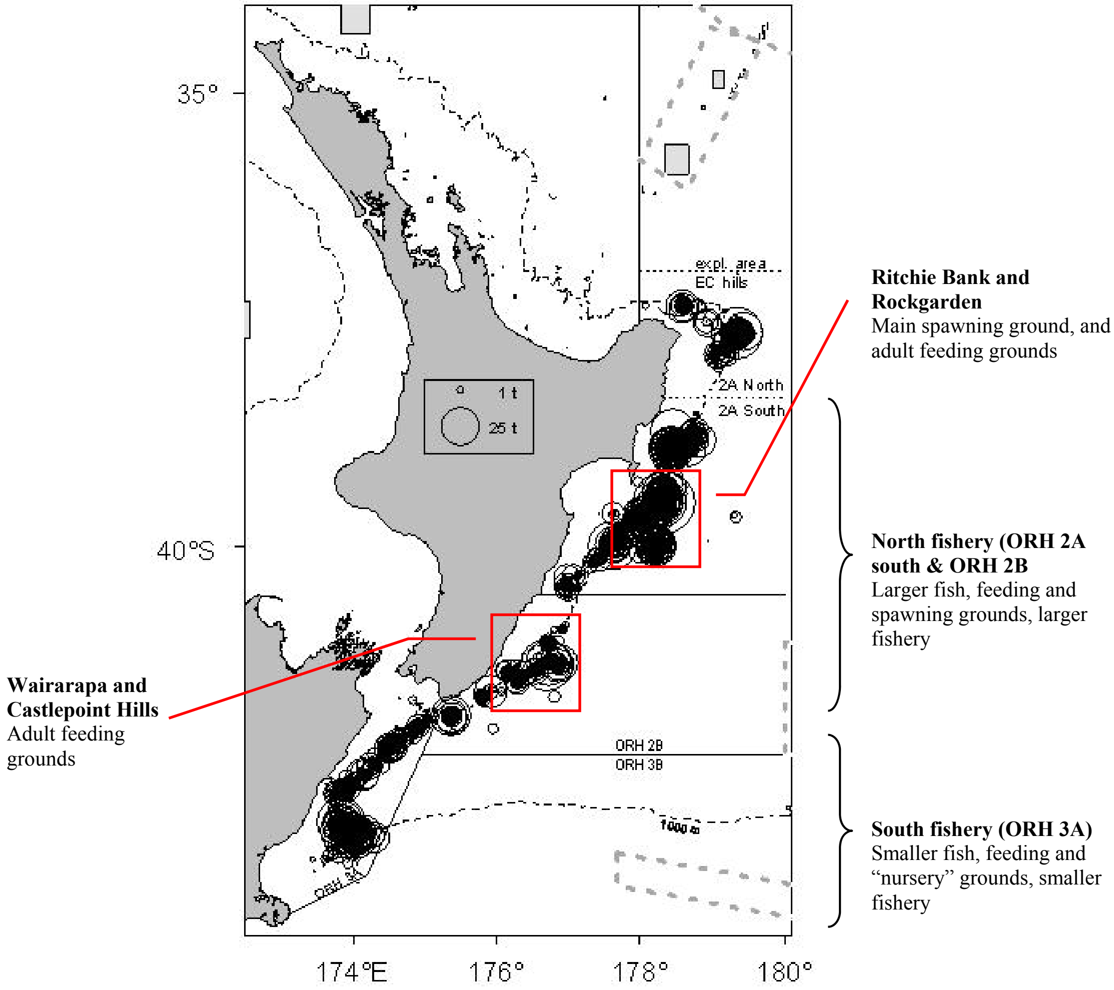


Figure 2: Catch (t) per tow of orange roughy in ORH 2A, ORH 2B, and ORH 3A for the five fishing years from 2006–07 to 2010–11 (circles, with area proportional to catch size), location of the fisheries assumed during stock assessment, and the location of the main spawning, feeding, and nursery grounds. Perimeters of Benthic Protection Areas (BPAs) closed to bottom trawling are marked with dashed grey lines, and seamounts closed to trawling are marked as shaded rectangles.

Table 5: Standardised CPUE and egg survey indices, and CVs for the East Cape stock, as used in the 2003 assessment, and an updated standardised CPUE index derived in 2011. -, no data.

	CPUE index 2003	CV(%)	Egg survey	CV(%)	CPUE index 2011	CV(%)
1993–94	1.00	12	-	-	0.95	23
1994–95	0.69	8	29 000	69	0.76	22
1995–96	0.60	8	-	-	0.61	23
1996–97	0.41	8	-	-	0.47	22
1997–98	0.25	7	-	-	0.27	23
1998–99	0.25	7	-	-	0.28	23
1999–00	0.22	9	-	-	0.23	23
2000–01	0.21	15	-	-	0.28	26
2001–02	0.22	16	-	-	0.23	27
2002–03	-	-	-	-	0.51	32
2003–04	-	-	-	-	0.50	30
2004–05	-	-	-	-	0.29	27
2005–06	-	-	-	-	0.37	28
2006–07	-	-	-	-	0.36	29
2007–08	-	-	-	-	0.27	28
2008–09	-	-	-	-	0.24	28
2009–10	-	-	-	-	0.20	27

4.1.2 Stock assessment

A stock assessment analysis for the East Cape stock was performed in 2003 using the stock assessment program, CASAL (Bull et al 2002) to estimate virgin and current biomass.

- The model was fitted using Bayesian estimation and partitioned the EC stock population by sex, maturity (the fishery was assumed to act on mature fish only) and age (age-groups used were 1–

70, with a plus group).

- The model estimated virgin biomass, B_0, and the process error for the CPUE indices. Catchability, q, was treated as a nuisance parameter by the model.
- The stock was considered to reside in a single area, and to have a single maturation episode modelled by a logistic-producing ogive where 50% of fish of both sexes were mature at age 26 and 95% at age 29.
- The catch equation used was the instantaneous mortality equation from Bull et al (2002) whereby half the natural mortality was applied, followed by the fishing mortality, then the remaining natural mortality.
- The size at age model used was the von Bertalanffy.
- No stock recruitment relationship was assumed.
- A Bayesian estimation procedure was used with a penalty function included to discourage the model from allowing the stock biomass to drop below a level at which the historical catch could not have been taken.
- Lognormal errors, with known (sampling error) CVs were assumed for the CPUE and egg survey indices. Additionally, process error variance was estimated by the model and added to the CVs from the CPUE indices.
- Confidence intervals were calculated from the posterior profile distribution of B_0 estimates, where the process error parameter was fixed at the value previously estimated.

4.1.3 Biomass estimates

Biomass estimates for this stock are given in Table 6 and the biomass trajectories, plotted against the scaled indices, are shown in Figure 3. The base case assessment of the EC stock included only the CPUE indices. An alternative assessment was carried out including the point estimate of biomass from the 1995 egg survey along with the CPUE indices. The CPUE indices agree well with the biomass estimates, with only the 1993–94 and 1997–98 indices departing from the biomass 95% confidence intervals. The egg survey biomass estimate, with the large associated CV, has little effect on the biomass trajectory.

Table 6: Estimates of virgin biomass (B_0), B_{MSY} (calculated as B_{MAY}, the mean biomass under a *CAY* policy), and B_{2003}, for the EC stock (with 95% confidence intervals in parentheses).

					B_{2003}		
Assessment	Index	B_0 (t)		B_{MSY} (t)	(t)	% B_0	
Base case	CPUE	21 100	(19 650–23 350)	6 300	5 100	24	(20–32)
Alternative	CPUE + Egg survey	21 200	(19 700–23 550)	6 380	5 200	25	(20–33)

The base case estimate of $B_{CURRENT}$ (the mid-year biomass in 2002–03) is 5100 t (24% B_0) with a 95% confidence interval of 3800 to 7550 t. This is almost twice the value of B_{2003} estimated for mid-year 1999–2000 in the previous assessment (Anderson 2000). The alternative assessment gives a very similar estimate of B_{2003}.

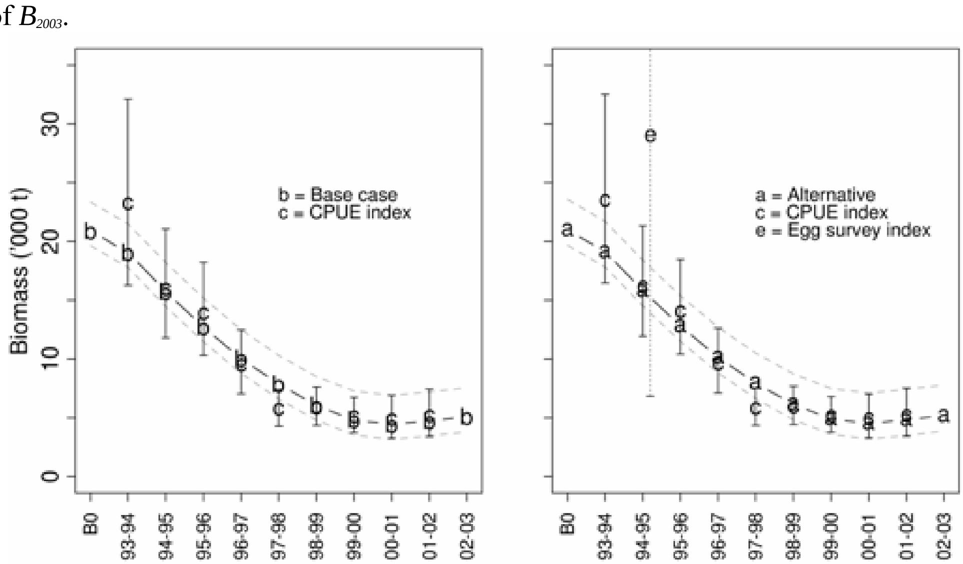


Figure 3: Estimated biomass trajectories for the base case and alternative model runs for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown, as is the CV calculated for the egg survey biomass estimate.

4.1.4 Yield estimates and projections

Estimates of *MCY* and *CAY* for the *EC* stock were calculated from large numbers of simulation runs using posterior profile sampling of B_0 and a series of trial harvest levels. These estimates, together with *MAY* (the mean catch with a *CAY* harvesting strategy) and *CSP* (current surplus production) are given in Table 7. *CSP* is driven by recruitment of fish spawned before the fishery began.

Table 7: Estimates of *MCY*, *CAY*, *MAY*, and *CSP* for the *EC* stock, with 95% confidence intervals in parentheses (all corrected for an assumed overrun of 5%).

Assessment	*MCY* (t)	*CAY* (t)	*MAY* (t)	*CSP* (t)
Base case	350	370	410	550
Alternative	350	370	410	550

4.2 Mid-East Coast stock (2A South, 2B, 3A)

There was no new information available that would change the accepted stock definition of the MEC orange roughy stock i.e. comprising ORH 2A South, ORH 2B, and ORH 3A.

The Mid-East Coast (MEC) stock assessment was updated in 2014 using the methods common to the four assessments performed in 2014 (see Orange Roughy Introduction). The previous model based assessment was in 2013 but that assessment used data which did not meet the quality threshold applied in 2014 (i.e., CPUE indices, wide-area acoustic survey and egg-survey estimates). In 2014, an age-structured population model was fitted to the data described in section 4.2.2 below.

4.2.1 Model structure

The model was single-sex and age-structured (1-120 years with a plus group) with maturity in the partition (i.e., fish were classified by age and as mature or immature). A single area and a single time step were used with two year-round fisheries defined by different selectivities (a "southern" fishery catching young fish (double-normal selectivity) and a "northern" fishery catching older fish (logistic selectivity). The spawning season was assumed to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The catch history was constructed from the catches in Tables 1 & 2, adding the catch over-run percentages in Table 4. The northern fishery combined catches from ORH 2A South and ORH 2B, and the southern fishery used ORH 3A. Natural mortality was assumed to be fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in the Orange Roughy Introduction.

4.2.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: a spawning biomass estimate from an acoustic survey (2013); a trawl-survey time series of relative biomass indices (1992–1994, 2010) with associated length frequencies (1992, 1994), and age frequencies and estimates of proportion spawning at age (1993, 2010); and length and age frequencies collected from the commercial fisheries, including four spawning-season age frequencies (1989-1991, 2010).

Research surveys

The MEC area has been surveyed using acoustic and trawl methods, and egg surveys have also been conducted. Not all survey data have been used in the 2014 assessment. The egg survey estimates have some quality issues associated with them; the 1993 survey data were post-stratified and "corrected" for turn-over of fish (Zeldis et al 1997). The 1993 egg-survey estimate was used in the 2013 assessment but was not considered to be reliable enough for the 2014 assessment (which had a higher "quality threshold"). Similarly, the wide-area acoustic survey estimates from 2001 and 2003 (Doonan et al 2003, 2004a) were rejected in 2014 as being not sufficiently reliable (in particular, the biomass estimates primarily came from mixed species marks and "orange roughy" marks identified subjectively; rather than being from easily identified spawning plumes).

Trawl survey data

A time series of pre-spawning season, random, stratified, trawl surveys were conducted in March–April on *RV Tangaroa* in 1992-94 and 2010 (Grimes et al 1994, 1996a, 1996b; Doonan & Dunn 2011). The 2010 survey was specifically designed to be comparable with the earlier surveys and to produce an abundance index for the MEC home grounds (Doonan & Dunn 2011). In addition to the relative biomass indices (Table 8), the survey data were analysed to produce length frequencies from all years and age frequencies from 1993 and 2010 (Doonan et al 2011). Also, estimates of female proportion spawning at age were produced for the 1993 and 2010 surveys (Ian Doonan, pers. comm.).

Table 8: Biomass indices and CVs used in the stock assessment.

Year	Trawl index (t)	CV (%)	Acoustic index (t)	CV (%)
1992	20 838	29		
1993	15 102	27		
1994	12 780	14		
2010	7 074	19		
2011				
2012				
2013			4 225	20

The biomass indices were fitted as relative biomass with a double-normal selectivity (it is apparent that the trawl survey did not fully select the largest/oldest fish) and an uninformed prior on the proportionality constant (q). The length frequencies from 1992 and 1994 were fitted as multinomial, as were the age frequencies from 1993 and 2010 (length frequencies from 1993 and 2010 had been used in the production of the age frequencies). The proportion spawning at age was assumed binomial at each age. Effective sample sizes were all taken from the 2013 assessment (Cordue 2014).

Acoustic survey estimate

The only reliable acoustic estimate of spawning biomass for MEC came in 2013 when a multi-frequency "AOS" survey was conducted (acoustic and optical gear mounted on the trawl headline, e.g., see Kloser et al 2011). Four areas were visited in 2013 but the only substantial spawning plume was seen in the "Valley" (a known spawning site near Ritchie Bank). Four snapshots were taken and the estimates from 38 kHz were averaged to produce a biomass index (Table 8).

The "standard" assumption in the 2014 stock assessments, for acoustic estimates from spawning plumes, is that they collectively cover "most" of the spawning biomass where "most" is taken to be 80%. However, for MEC, only one spawning plume was found and it was in a very small area. There are many potential sites in the MEC for spawning plumes. For these reasons, "most" was taken to be 60% in the base model (and sensitivities were done at 40% and 80%). That is, the acoustic estimate was fitted as relative biomass with an informed prior: lognormal (mean = 0.6, CV = 19%) for the base model.

Commercial age and length frequencies

As in 2011 and 2013, composition data were also used: length frequency samples from the northern commercial fishery (ORH 2A South and ORH 2B) for 16 years between 1988–89 and 2009–10, and from the southern commercial fishery (ORH 3A) for nine years between 1989–90 and 2008–09, and age frequency samples from commercial landings of the spawning fishery in ORH 2A south in 1989, 1990, 1991. The otoliths from the 1989–91 samples were re-aged for the 2013 assessment using the new ageing protocol (Tracey et al 2007). In addition, age samples taken from a single vessel in the 2010 spawning season were also used. These had been aged with the new protocol but because they were from a single vessel and a fishery 20 years later than in 1990 the age frequency was fitted with its own selectivity. The age frequencies from 1989-91 were assumed to be from spawning fish (i.e., no selectivity fitted). The composition data were all assumed to be multinomial and effective samples sizes from the 2013 assessment were used (except the southern fishery length frequencies were down-weighted following the iterative reweighting procedure of Francis (2011)).

4.2.3 Model runs and results

In the base model, natural mortality (*M*) was fixed at 0.045. There were numerous MPD sensitivity runs and six main sensitivities are presented in this report: estimate *M*; down-weight the trawl indices; separate selectivity for spawning age frequencies; mean acoustics *q* prior = 0.4; and the LowM-Highq and HighM-Lowq "standard" runs (see Orange Roughy Introduction).

In the base model, the main parameters estimated were: virgin biomass (B_0), the maturity ogive, the two fishery selectivities, the trawl survey selectivity, the 2010 age frequency selectivity, and year class strengths (YCS) from 1881 to 1996 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). Additional estimated parameters included the CV of the length-at-age parameters and the proportionality constants (*q*s)for the trawl survey time series and the 2013 acoustics estimate.

Model diagnostics

The MPD fits to the biomass indices were excellent (Figure 4), although the MCMC fit was only just adequate for the trawl survey indices, particularly to the 2010 index (Figure 5). The poorer MCMC fit to the 2010 trawl index when compared to the MPD fit occurred because the MPD pattern of YCS did not match the posterior distribution of the same quantities, showing much greater year-to-year variation than seen in the MCMC posterior (Figure 6). This result highlights the difference between MPD estimates and MCMC estimates: the MPD finds the single vector of parameters which give the best fit to the data, while the MCMC procedure finds the parameter space that best explains the data. There is no reason why the MPD has to be in the "middle" of the posterior distribution, here we have an example where the MPD estimates are in the tail of the posterior distribution.

The MCMC fit to the acoustics index had also degraded when compared to the MPD fit (see Figures 4 and 5), as well as estimating a lower acoustics *q* (Figure 7). The cause of this is the same as for the 2010 trawl index; the MPD spawning biomass trajectory almost exactly matched the 2013 acoustic estimate but, given the less variable MCMC YCS trajectory, the resulting MCMC biomass trajectory was shifted higher (and the acoustic *q* shifted lower to compensate).

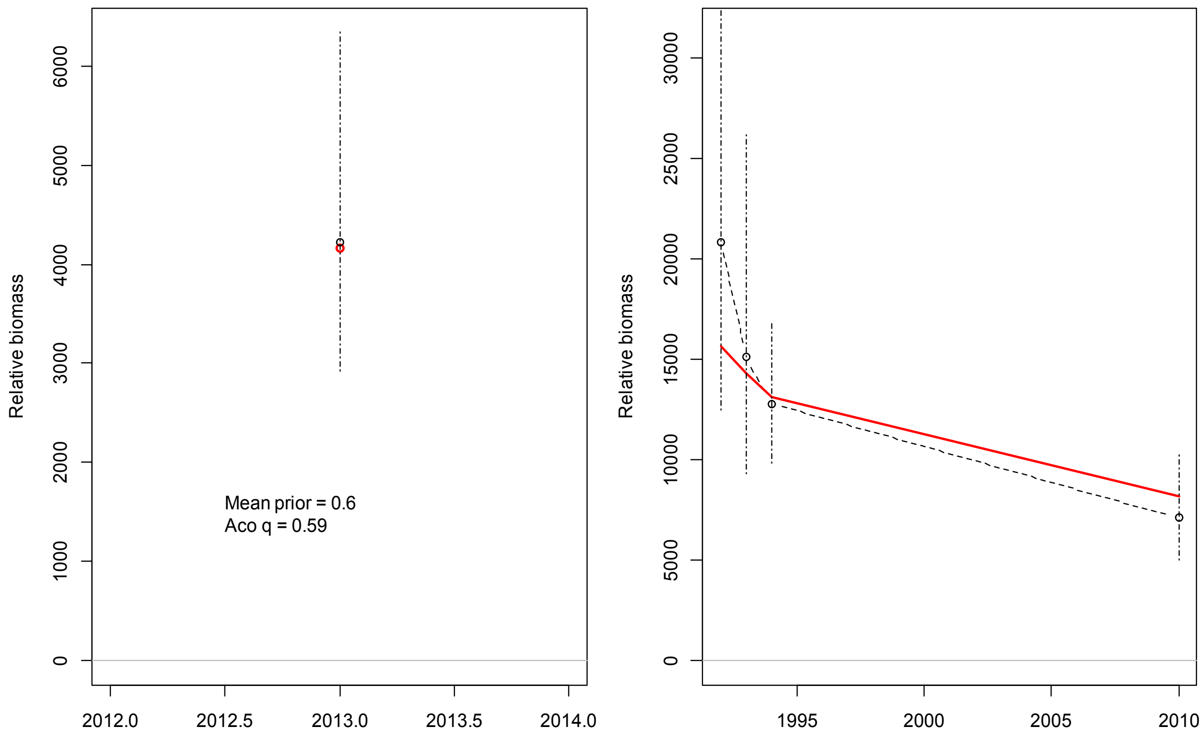


Figure 4: MPD fit to biomass indices: left: acoustic-survey spawning biomass index (fitted with an informed *q* prior, mean = 0.6; MPD estimated *q* = 0.59); right: *Tangaroa* trawl-survey indices. Vertical lines are 95% CIs.

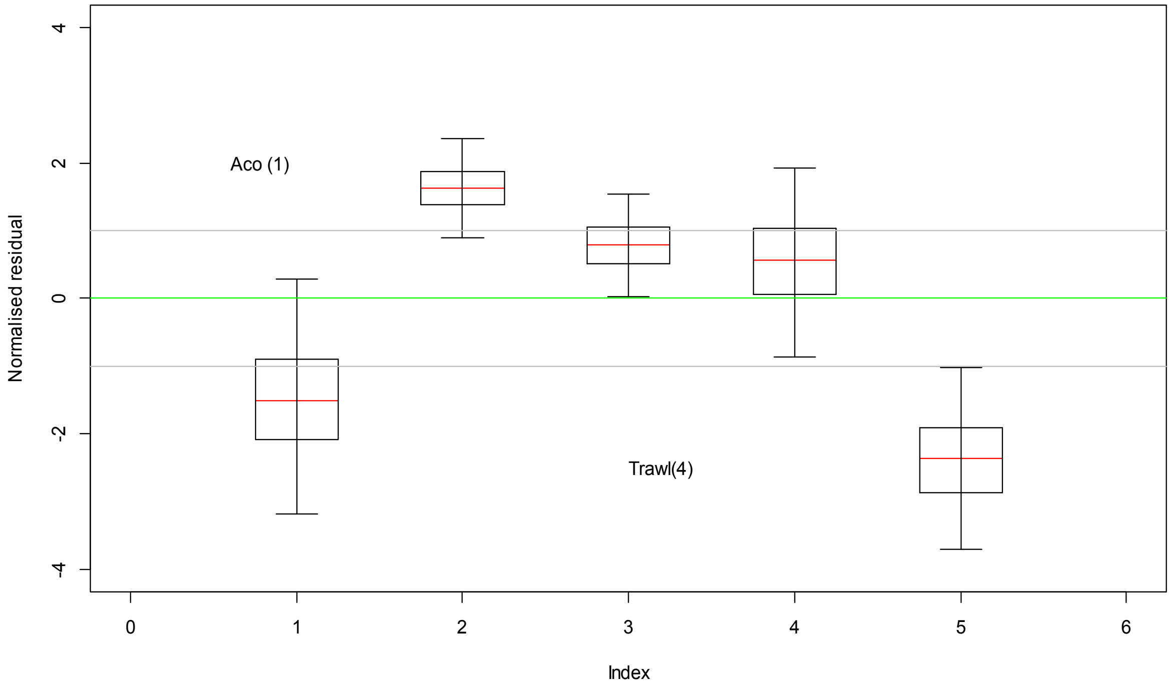


Figure 5: MCMC base: normalised residuals for the biomass indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution. "Aco" denotes the acoustic estimate (2013). "Trawl" denotes the *Tangaroa* trawl-survey time series (1992-94, 2010).

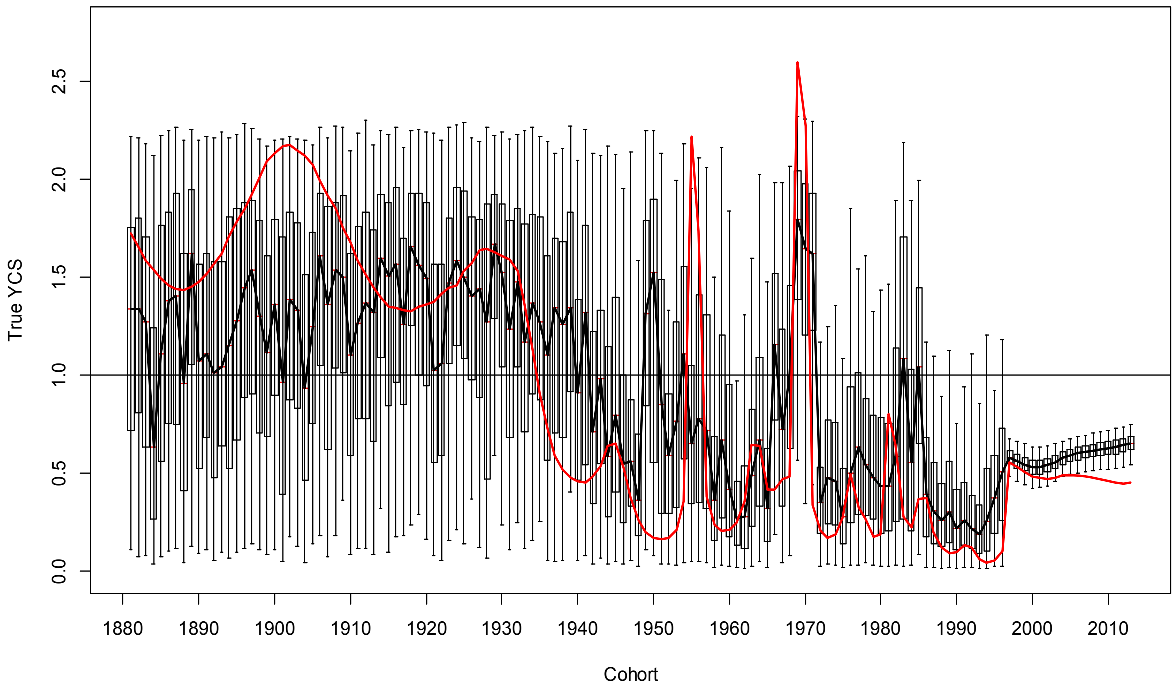


Figure 6: Base model: MCMC estimated "true" YCS (R_y/R_0) (in black). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The MPD estimates are shown in red.

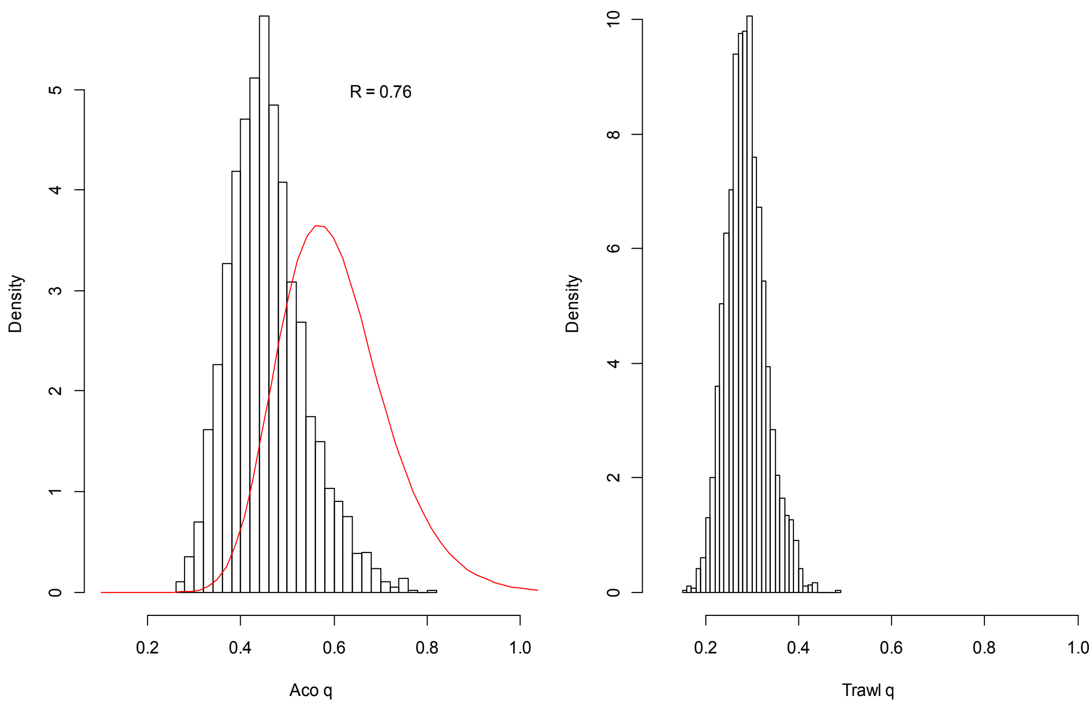


Figure 7: Base model MCMC diagnostics: prior and posterior distributions for the acoustic *q* (prior in red, posterior black histogram) (left); posterior distribution for the trawl-survey *q* (the prior was uninformed) (right). R = 0.76 is the ratio of the mean of the acoustic *q* posterior to the mean of the prior.

The MPD fits to the commercial length frequencies were adequate (Figures 8 and 9). They could never be very good because the length frequencies show a great deal of year-to-year variability, as evidenced by the annual mean lengths (Figure 10). The model predictions of annual mean length are necessarily fairly smooth from year-to-year; as they are only able to track the main trend but not the annual jumps (Figure 10).

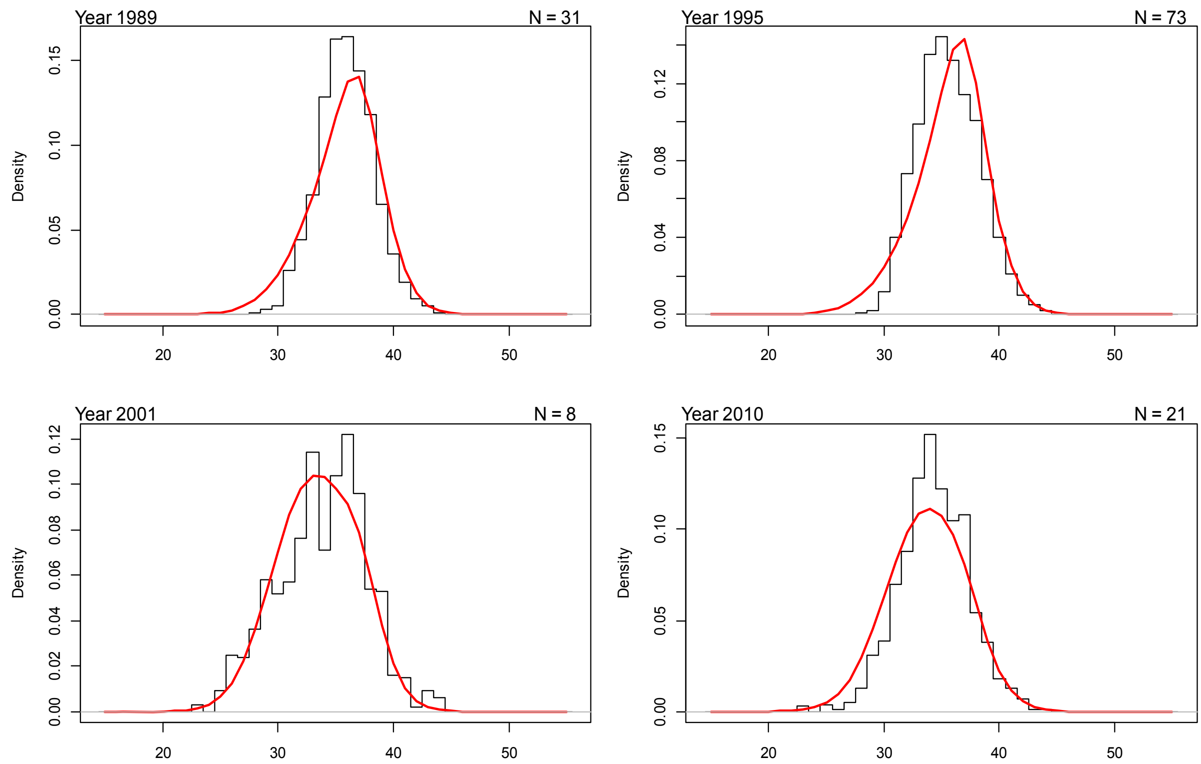


Figure 8: Example MPD fits to northern fishery length frequencies (N is the assumed effective sample size in the given year; x-axis is fish length (cm)). Observations are black lines; model predictions are the red lines.

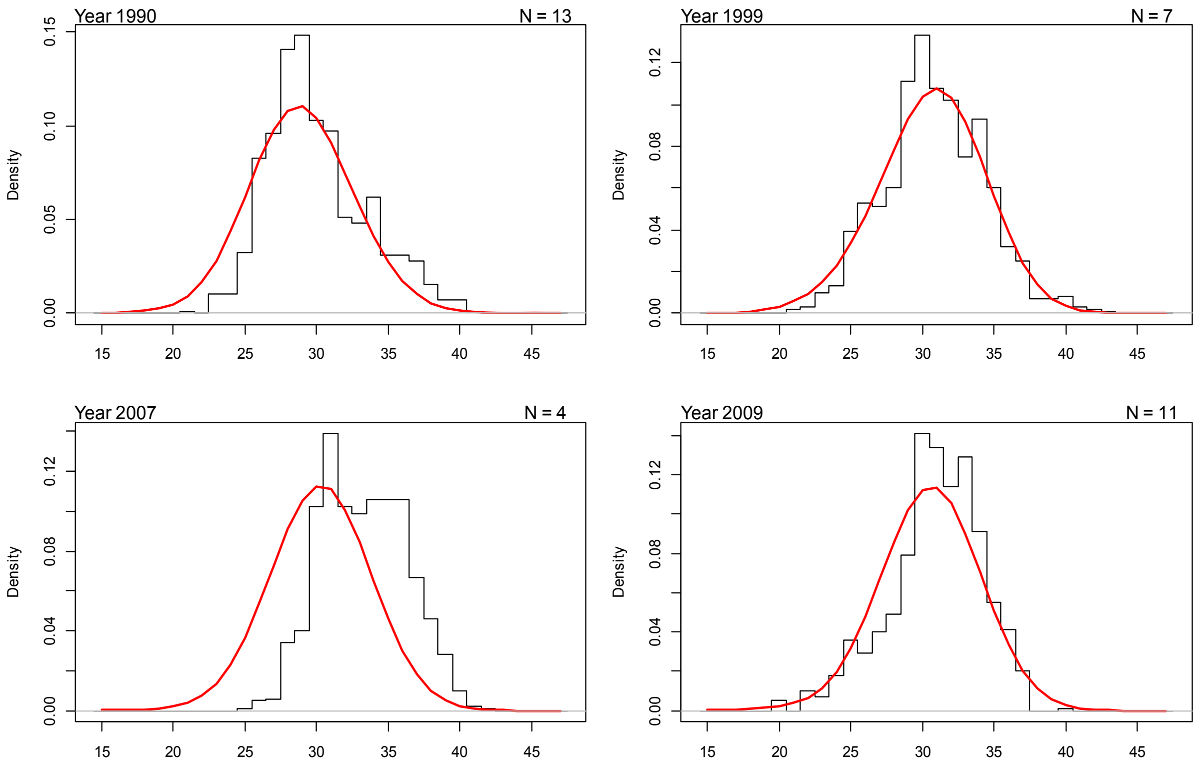


Figure 9: Example MPD fits to southern fishery length frequencies (N is the assumed effective sample size in the given year; x axis is fish length (cm)). Observations are black lines; model predictions are the red lines.

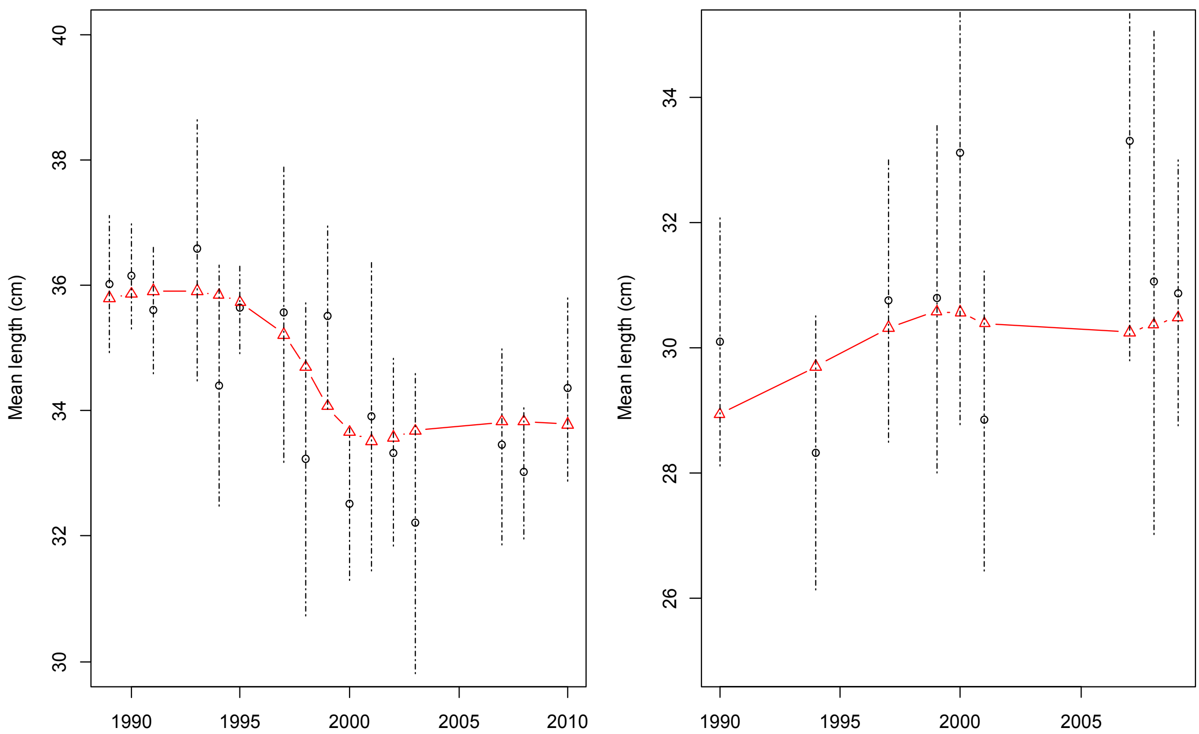


Figure 10: Annual mean lengths from the commercial length frequencies (northern fishery on the left, southern on the right) with 95% CIs (black, circles, dashed vertical lines) and the base model predictions (red, triangles, solid lines).

The MPD fits to the trawl-survey length frequencies and estimates of proportion spawning at age are good (Figure 11). It is notable that the model fits the different shape of the proportion spawning estimates in 1993 and 2010 (Figure 11). The spawning-season age frequencies are only adequately fitted (Figure 12). There is a misfit for the young ages (except for 2010 which had its own selectivity) as these data compete with the proportion spawning-at-age data to define the maturity ogive (see Figure 11 – young fish are spawning according to the proportion spawning data). In response to the misfit in Figure 12, a sensitivity run was done where the 1989-91 spawning age frequencies were allowed to have a logistic selectivity. This improved the fit substantially and raised the model estimate of the 2014 stock status from 14 to 17% B_0. The base model was preferred to be consistent across the four orange roughy stocks assessed in 2014, with the maturity ogive used to define the spawning-season selectivity and age frequencies.

The fit to the trawl-survey age frequencies is excellent, which should be expected given the large effective sample size of N = 200 (Figure 13). A number of sensitivity runs were done with alternative data weighting, including down-weighting the trawl-survey age frequencies, which demonstrated that the model was robust to a wide range of assumptions. For example, the only runs that made a substantial difference to the MPD estimates of stock status were doubling the acoustic index (10.2% B_0 compared to the base estimate of 6.5% B_0) and assuming deterministic recruitment (25.8% B_0); the other 16 runs had MPD estimates in the range 4–9% B_0.

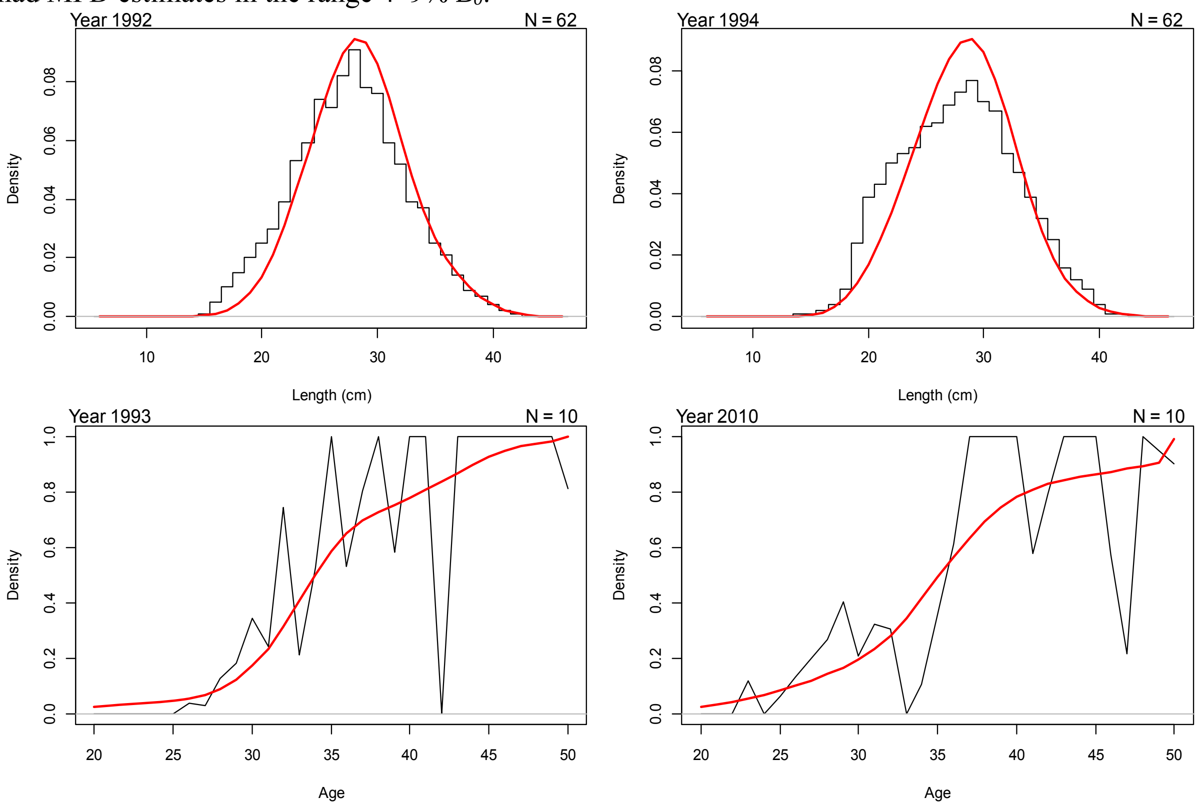


Figure 11: Base, MPD fits to trawl-survey length frequencies (N is the assumed effective sample size in the given year) and proportion spawning-at-age (N =10 is the binomial sample size assumed for each age). Observations are black lines; model predictions are the red lines.

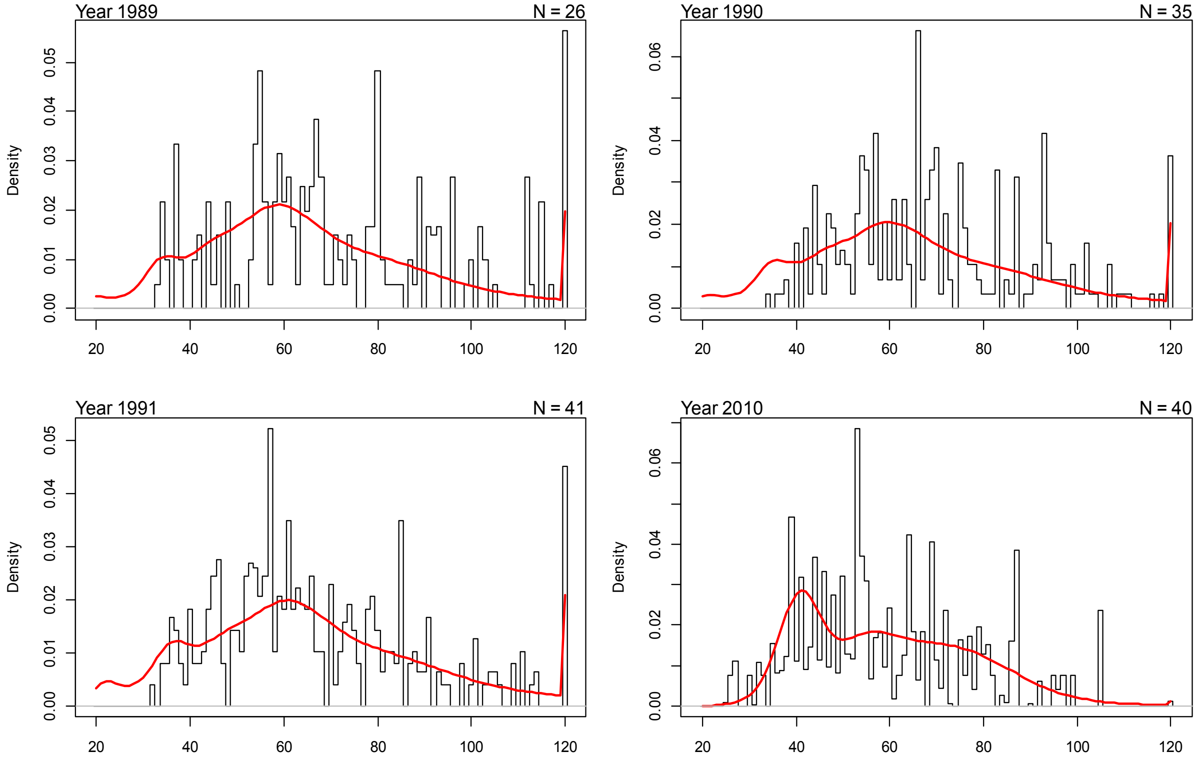


Figure 12: Base, MPD fit to spawning-season age frequencies (N is the assumed effective sample size in the given year). Observations are black lines; model predictions are the red lines.

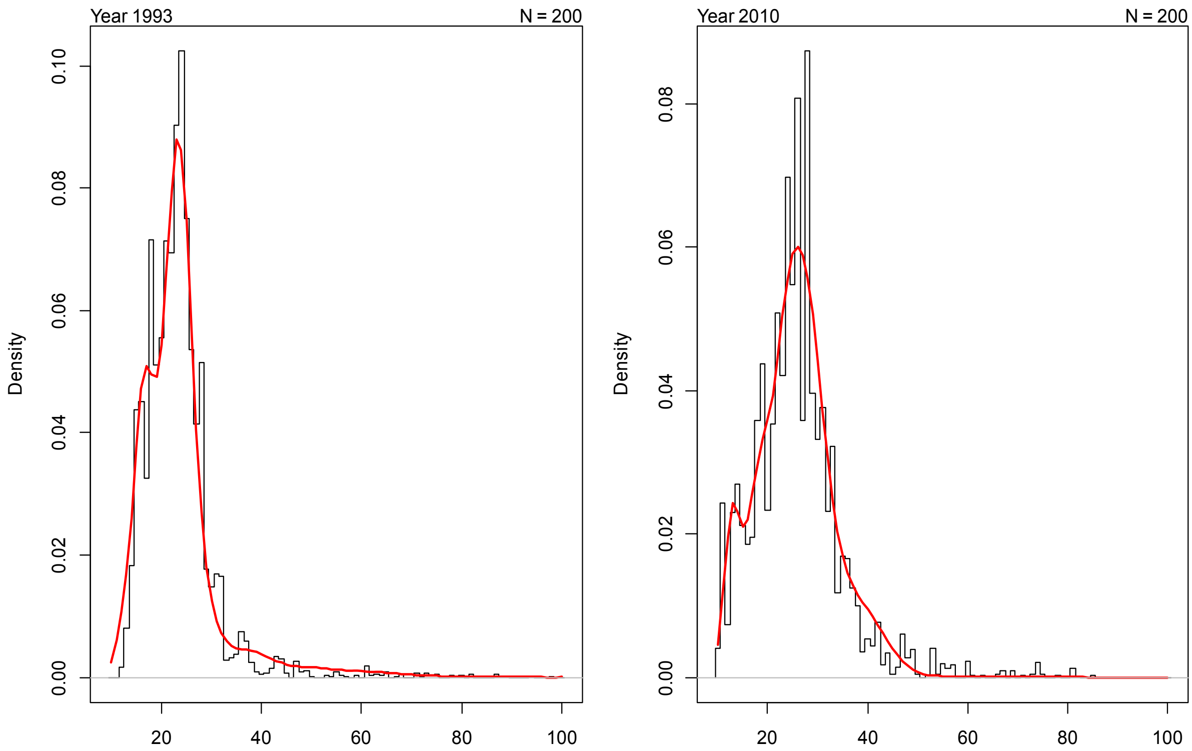


Figure 13: Base, MPD fit to trawl-survey age frequencies (N = 200 is the assumed effective sample size). Observations are black lines; model predictions are the red lines.

MCMC results

MCMC convergence diagnostics were very good for the base model and sensitivities. Virgin biomass (B_0) was estimated to be about 100,000 t for all runs (Table 9). Current stock status was similar for the base and the estimate-*M* run (Table 9). The slightly lower stock status when *M* was estimated reflects the lower estimate of M (0.032 rather than 0.045). Down-weighting the trawl indices (by adding process error CV of 20%) reduced the magnitude of the normalised residuals and raised the median estimate of 2014 stock status from 14 to 16% B_0 (Table 9). Giving the 1989–91 spawning age frequencies a selectivity improved the fit to younger age fish, decreased the estimate of B_0 from 95 000 t to 91 000 t and increased estimated stock status from 14 to 17% B_0 (Table 9). The reduction in the mean of the acoustic q from 0.6 to 0.4 increased the median estimate of stock status to 19% B_0, but the median estimate was still below the soft limit (Table 9). The two "bounding runs" where M and the mean of the acoustic q were shifted by 20%, still had median estimates under the soft limit, with the "LowM-Highq" run at the hard limit (Table 9). Other sensitivities not reported here included several where the effective sample size on age frequencies was appreciably increased or decreased; in all cases, this had little impact on the estimates of stock status.

Table 9: MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model, and the six following sensitivity runs: a) estimating natural mortality; b) down-weighting the trawl indices by adding 20% process error to the CV; c) adding a selectivity to spawning age frequencies for 1989–91; d) reducing the mean acoustic catchability coefficient, q, from 0.6 to 0.4; e) decreasing M and increasing acoustic q by 20%; and f) increasing M and decreasing acoustic q by 20%.

Assessment	*M*	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base model	0.045	95	87–104	14	9–21
a) Estimate M	0.032	104	96–112	11	7–16
b) Down-weight trawl	0.045	97	88–108	16	11–22
c) Spawn AF selectivity	0.045	91	83–102	17	12–24
d) Mean aco. q = 0.4	0.045	100	92–112	19	13–26
e) LowM-Highq	0.036	96	90–103	10	7–15
f) HighM-Lowq	0.054	99	89–114	19	13–27

The estimated fishery selectivities showed the northern fishery taking fish over 30 years with the southern fishery primarily taking fish from 20-40 years (Figure 14). The trawl-survey selectivity primarily sampled fish from 10-70 years with peak selection from 20-30 years (Figure 14). The 2010 age frequency appears to have been a subset of spawning fish focussed on those from about 50-90 years (Figure 14).

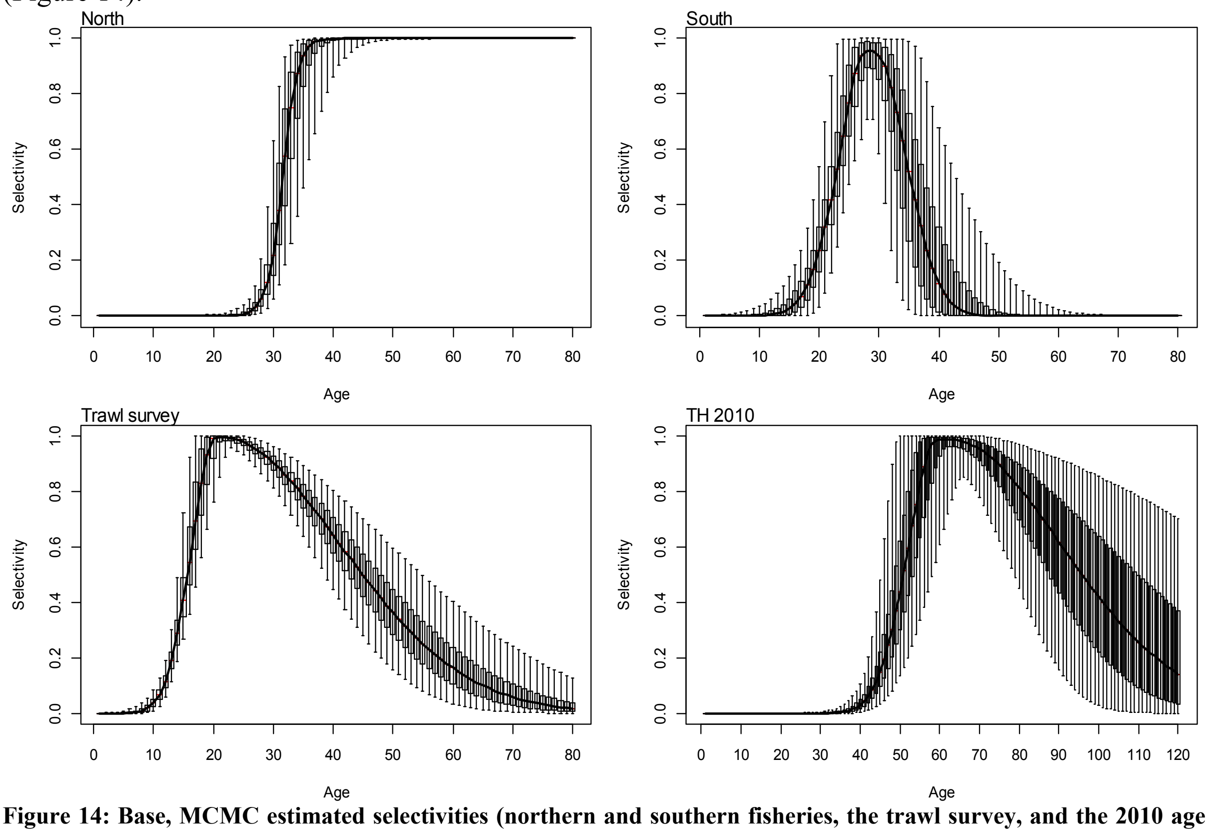


Figure 14: Base, MCMC estimated selectivities (northern and southern fisheries, the trawl survey, and the 2010 age frequency). The box at each age covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated YCS show strong variation across cohorts and exhibit a long-term trend, with recruitment well below average since the early 1970s (Figure 15). The most recent 10 years of estimates, 1986–

1995 (those resampled for short-term projections) are well below average.

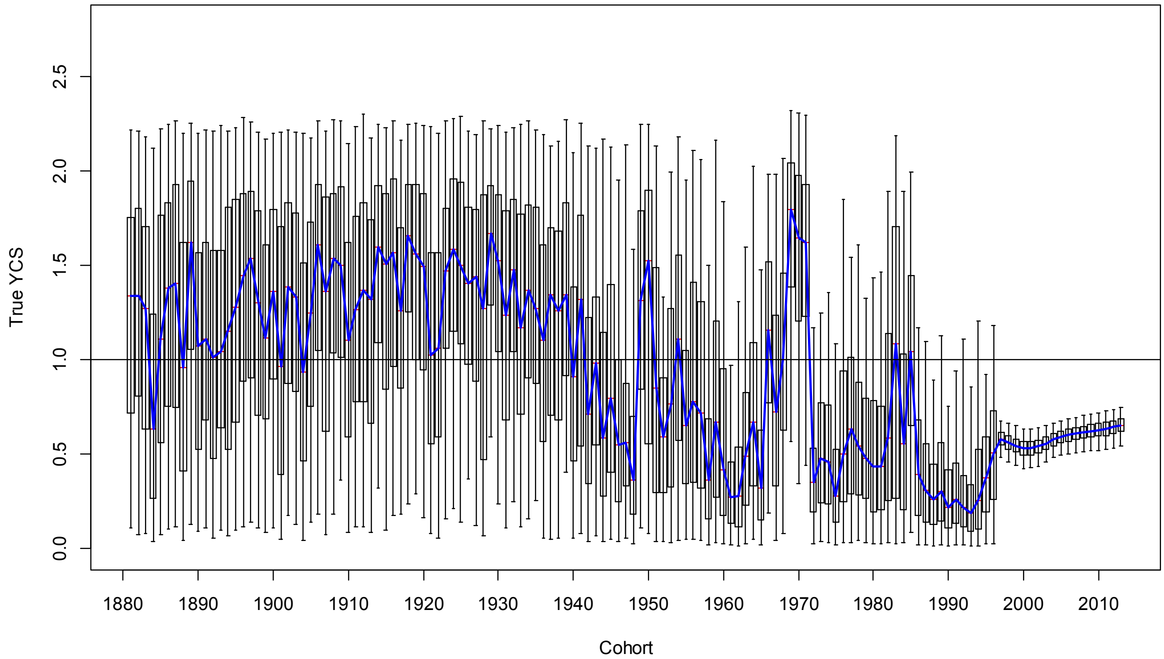


Figure 15: Base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory shows an increasing trend before the start of fishery as the above average recruitment estimated by the model feeds into the spawning biomass (Figure 16). Then there is a steep decline from the start of fishery until the year 2000 when the biomass reached 10% B_0, after which there was a slow increase (Figure 16).

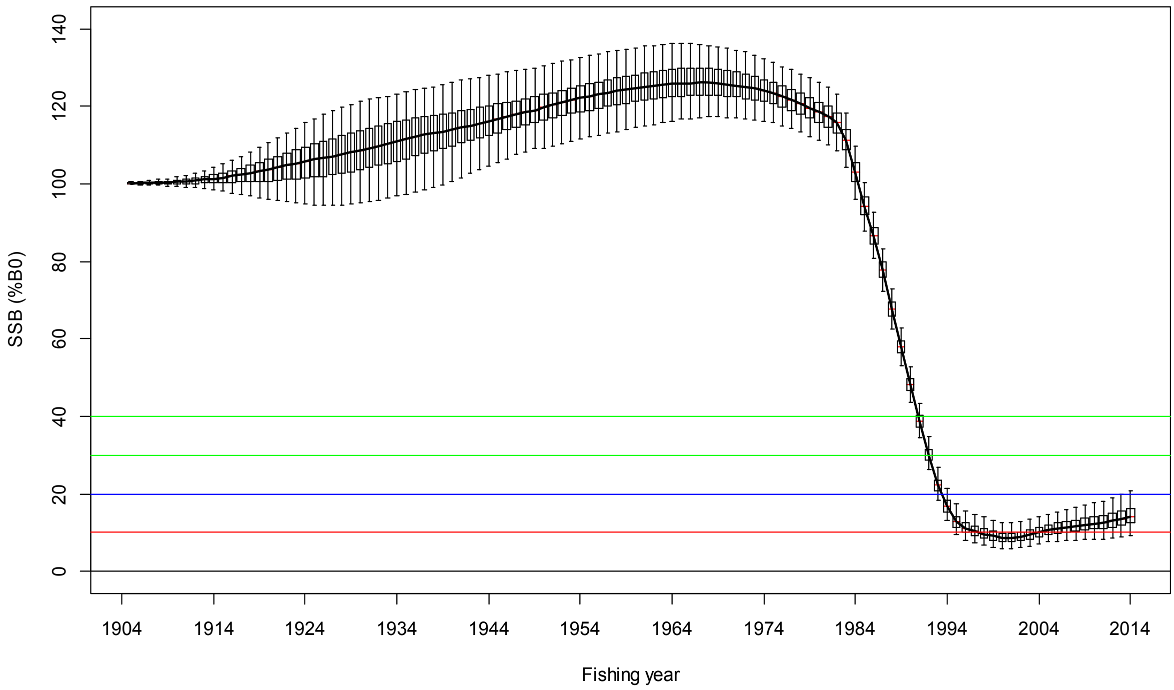


Figure 16: Base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit, 10% B_0 (red), soft limit, 20% B_0 (blue), and biomass target range, 30–40% B_0 (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ drives the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was above the target range ($U_{30\%B0}$–$U_{40\%B0}$) from 1984 to 2012 (Figure 17). In the last two years, fishing intensity has decreased to within the target range.

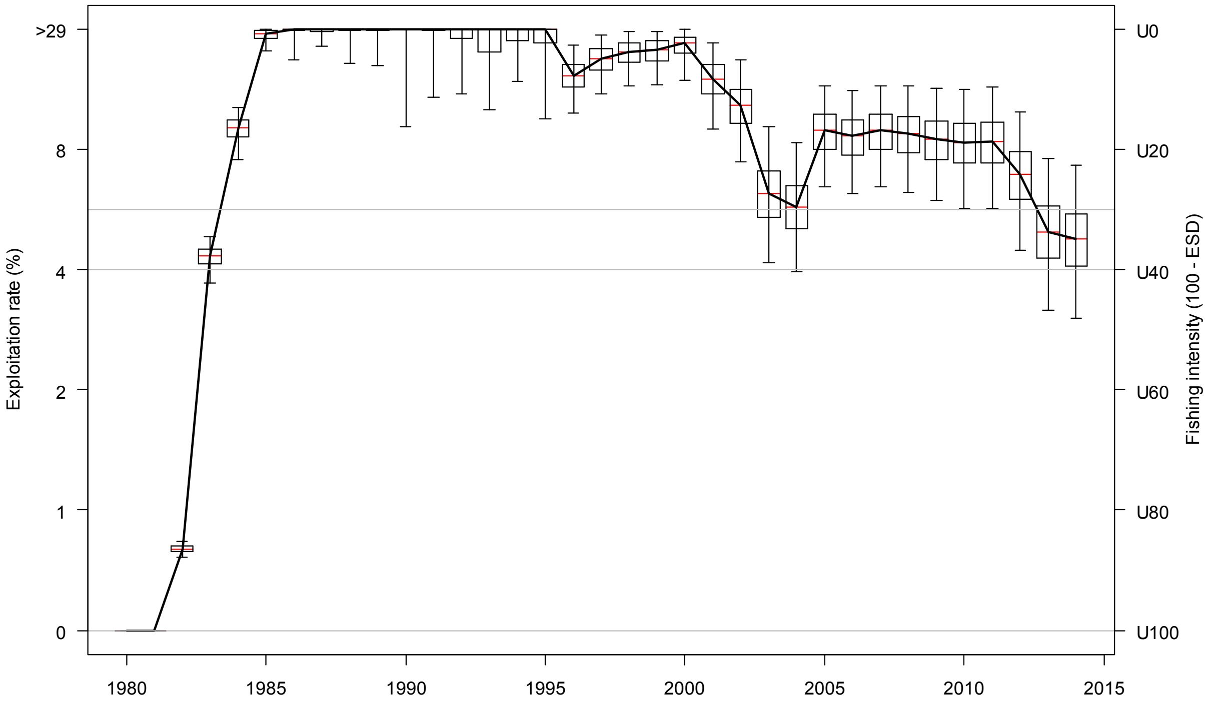


Figure 17: Base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30-40% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 10).

There are several reasons why deterministic B_{MSY} is not a suitable target for use in fisheries management. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is often poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

Table 10: Base, MCMC estimates of deterministic equilibrium spawning stock biomass (SSB) and long-term yield (% B_0 and tonnes) for U_{MSY} and $U_{35\%B0}$. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	22.5	2.3	2214
	95% CI	21.8–23.0	2.3–2.4	2048–2415
$U_{35\%B0}$	Median	35.0	2.2	2075
	95% CI	35.0–35.0	2.2–2.2	1916–2264

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for catch at the current catch limit of 930 t (with a 5% catch over-run assumed). Projections were done just for the base model. At the current catch limit (930 t), SSB is predicted to increase slowly over the next five years but still be well below the soft limit in 2019 (Figure 18). The estimated minimum time to rebuild (assuming zero catch and requiring a 70% probability of being above the lower bound of the 30–40% B_0 target range), is 21 years (T_{min}) (Figure 19).

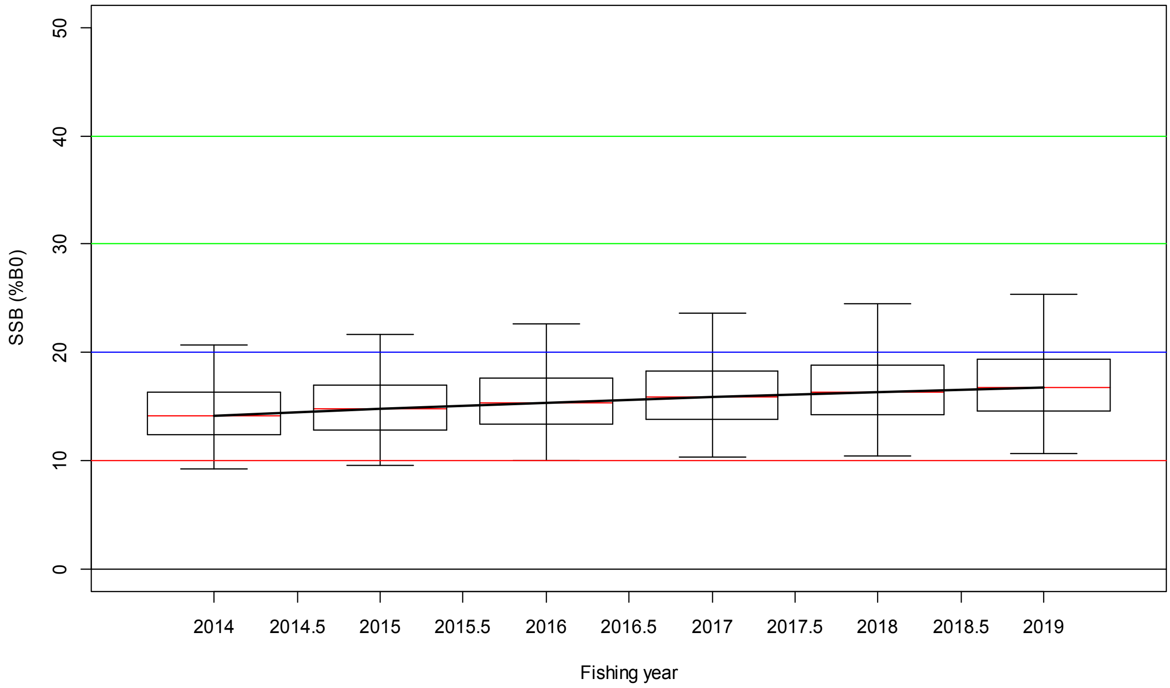


Figure 18: Base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. An annual catch at the current catch limit of 930 t was assumed (with a 5% catch over-run in each year). The target range (30–40% B_0) is indicated by horizontal green lines, with the soft limit (20% B_0) in blue and the hard limit (10% B_0) in red.

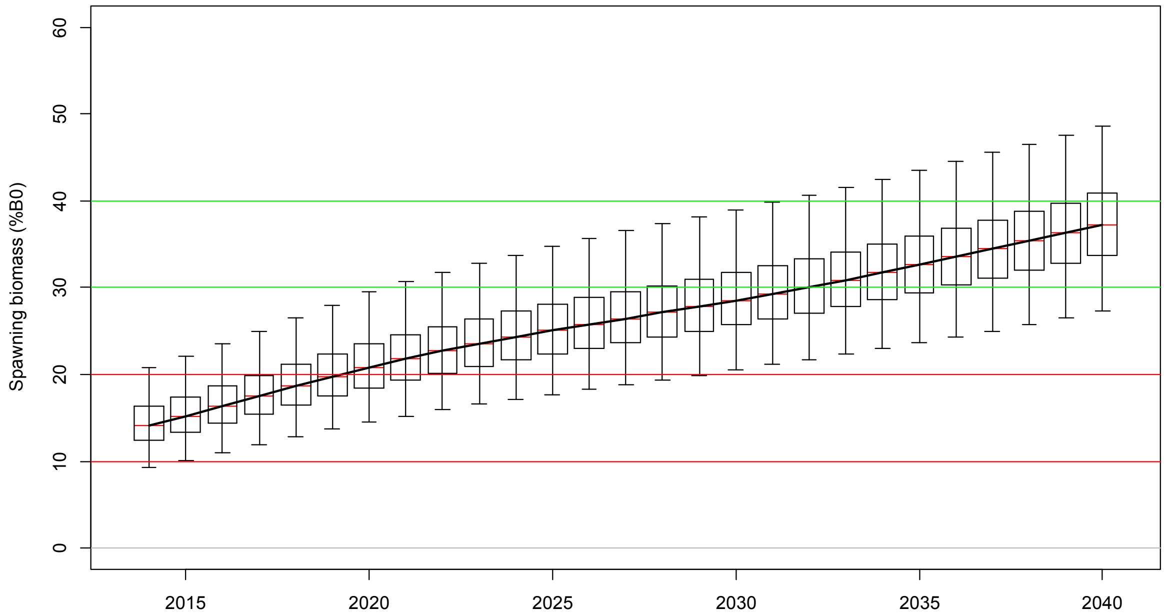


Figure 19: Base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The annual catch used in these projections is zero tonnes. The target range (30–40% B_0) is indicated by horizontal green lines, with the soft limit (20% B_0) in blue and the hard limit (10% B_0) in red.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

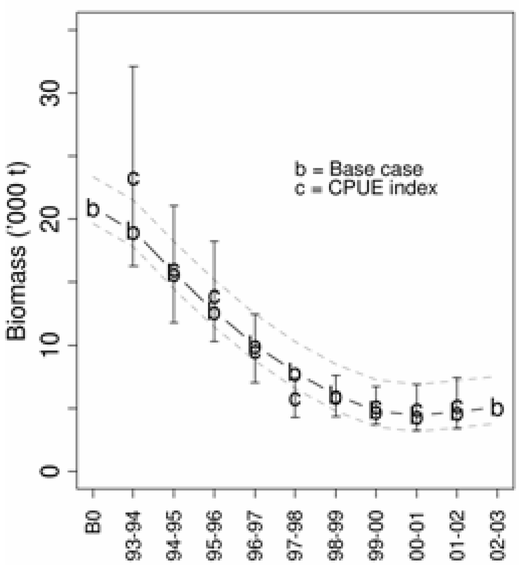
Orange roughy in ORH 2A, 2B and 3A are treated as two biological stocks based on the location of spawning grounds. These stocks are managed and assessed separately however some mixing has been shown to occur. The 2A North stock spawns around the East Cape hills off of the North Island. The 2A South, 2B and 3A stock is assumed to spawn on the Ritchie Bank.

For orange roughy stocks, the current management target is a biomass range from 30–40% B_0.

- **ORH East Cape Stock (2A North)**

Stock Status	
Year of Most Recent Assessment	2003
Assessment Runs Presented	A base case with one alternative
Reference Points	Management Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold:-
Status in relation to Target	B_{2003} was 24% B_0, which was Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	B_{2003} was Unlikely (< 40%) to be below the Soft Limit, and Very Unlikely (< 10%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectory for the base model run for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined in the early 1990s but appeared to stabilise at around 5000 t.
Recent Trend in Fishing Mortality or Proxy	*F* has declined along with the agreed catch limit and remains stable at the current catch level of 200 t.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2003)	
Stock Projections or Prognosis	The estimated *CAY* (370 t) and *MAY* (410 t) were both greater than the catch limit of 200 t, and this suggested the stock would start to rebuild.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Type 1 - Quantitative stock assessment	
Assessment Method	Statistical catch-at-age model implemented in CASAL with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2003	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	- Catch data - Standardised CPUE data - 1994–95 ORH egg survey	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

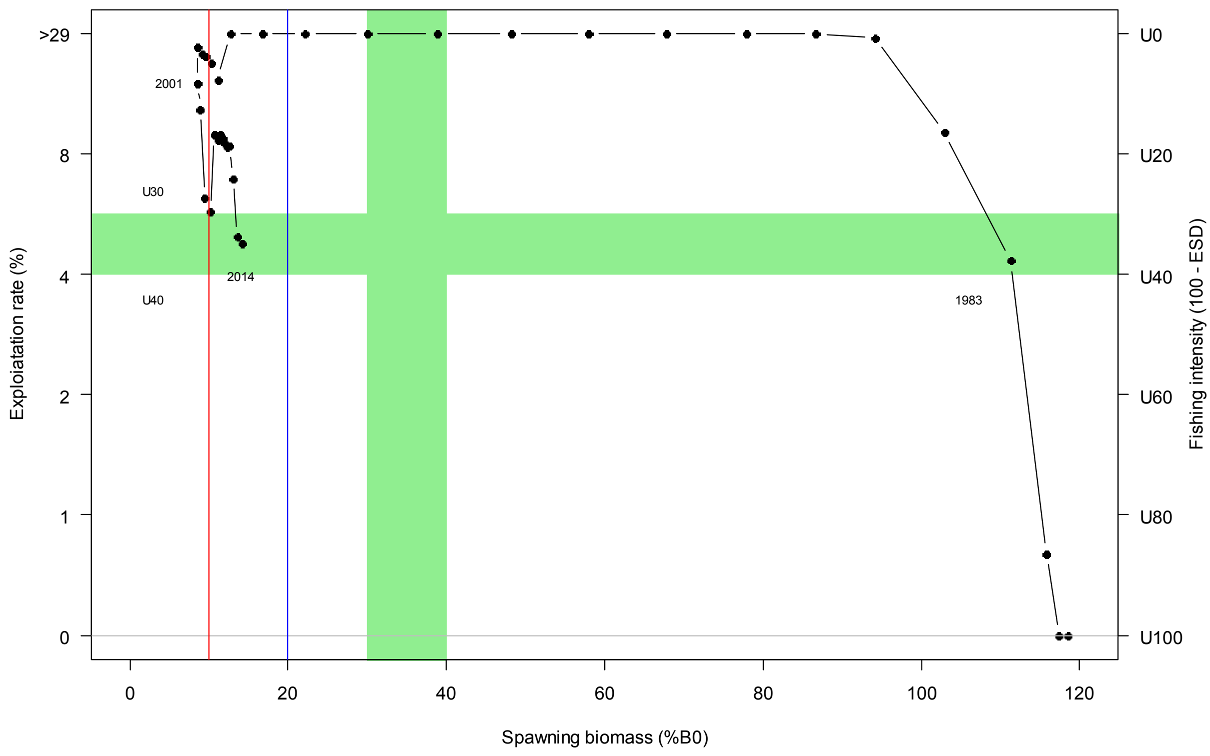
Qualifying Comments
The most recent assessment (2003) is now 11 years out-of-date. In recent years, the ability of stock assessment models that assume deterministic recruitment for orange roughy stocks to reflect current or projected stock status has been called into question.

Fishery Interactions
The main bycatch species are cardinalfish and alfonsino. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Protected species bycatch includes seabirds and corals.

- **ORH Mid-East Coast Stock (2A South, 2B, 3A)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{40\%B0}$
Status in relation to Target	B_{2014} was estimated to be 14% B_0 Very Unlikely (< 10%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2014} is Likely (> 60%) to be below the Soft Limit B_{2014} is Unlikely (< 40%) to be below the Hard Limit
Status in relation to Overfishing	Fishing intensity in 2014 was estimated at $U_{35\%B0}$ Overfishing is About as Likely as Not (40–60%) to be occurring

Historical Stock Status Trajectory and Current Status



Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30-40% B_0 and the corresponding exploitation rate (fishing intensity) range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning biomass has been slowly increasing since about 2000.
Recent Trend in Fishing Intensity or Proxy	Estimated fishing intensity has been declining in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At the current catch limit, the stock is projected to increase slowly over the next 5 years but still be below the soft limit in 2019. The minimum rebuild period to reach 30% B_0 with 70% probability is estimated to be 21 years with no catch.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For the current catch and catch limit (in the short term): Soft Limit: Very Likely (> 90%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For the current catch and catch limit: As Likely as Not (40–60%)

Assessment Methodology and Evaluation	
Assessment Type	Level 1 - Full quantitative stock assessment
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions

Assessment Dates	Latest assessment: 2014	Next assessment: 2018
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Acoustic biomass estimate (2013)	1 – High Quality
	- Trawl-survey biomass indices (1992–94, 2010), age frequencies (1993, 2010), length frequencies (1992, 1994), proportion spawning at age (1993, 2010)	1 – High Quality
	- Spawning-season age frequencies (1989–91, 2010)	1 – High Quality
	- Commercial length-frequencies (1989–90 to 2009–10)	1 – High Quality
Data not used (rank)	- CPUE indices	3 – Low Quality (unlikely to be indexing stock-wide abundance)
	- 2002 spawning-season age frequency	2 – Mixed Quality (needs to be re-aged)
	- Wide-area acoustic estimates	2 – Mixed Quality (too much potential bias due to target identification and mixed species issues)
	- Egg survey estimates	2 – Mixed Quality (too much potential bias due to survey design assumptions not being meet)
Changes to Model Structure and Assumptions	A more stringent data quality threshold was imposed on data inputs (e.g., wide-area acoustics, egg survey, and CPUE indices not used).	
Major Sources of Uncertainty	-The proportion of the spawning stock biomass that was indexed by the 2013 acoustic survey (little survey effort has been expended in this area relative to other orange roughy grounds). -Patterns in year class strengths are based on only 5 years of age composition data.	

Qualifying Comments
Estimates of stock biomass are sensitive to the means of the *q* priors. In addition, when higher CVs were used for the informed acoustic *q* priors, the median estimates of biomass and stock status were slightly higher and the confidence intervals were wider with a much higher upper bound.

Fishery Interactions
Fish bycatch is estimated to make up about 20% of the total catch in this fishery. The main bycatch species are alfonsino, smooth oreo and hoki. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Observed incidental captures of protected species include corals and very small numbers of seabirds.

6. FOR FURTHER INFORMATION

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